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FOREST INSECT INVESTIGATIONS

ESTIMATING PINE BEETLE LOSSES DURING PERIOD OF ATTACK

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Examination of western yellow pine stands are often made during the summer and fall while flight and attacks are in progress. The examiner finds single trees and groups attacked here and there through the stand. He is anxious to know whether the infestation is increasing or decreasing but realizing that what he finds on the area is only a portion of the total attack, and not knowing what proportion he is quite unable to decide just what the current infestation is doing.

There is a distinct need, therefore, for data which will indicate what percentage of the total loss is apt to be found at any date so that current cruising data can be interpreted. Such data has been secured for the southern Oregon-northern California area during the past seven years; and the percentages determined are sufficiently accurate to be useful. They have been tested in making estimates of losses from fall surveys, and such estimates have come reasonably close to the final figures.

Unfortunately the data obtained is only applicable to the southern Oregon-northern California region. Further south the attack period is spread over a much longer season and hence the percentages will not apply. However, curves for other areas can be approximated, if the dates of first and last attacks are known. On a graph with dates as abscissae and percentages as ordinates, if a straight line is drawn between 0 per cent on the date of first attack to 100 per cent on the date of last attack, the line will approximate the percentages for other dates. The difficulty, of course, is in determining with accuracy the time of the appearance of first and last attacks for any region. When these two points have been determined, the rest is easy.

THE DATA

The graphs shown in Chart 1 and 2 have been built up only from the data secured in the annual surveys of the southern Oregon-northern California region, where standard cruising methods have been used. These methods consist of cruising and marking section plots with a three-man crew, compassman, and two spotters, with each spotter covering a five-chain strip.

From 1923 to 1926 the current annual loss was only tallied and in some cases blazed, and then completely checked and marked the following year. This caused confusion, however, for in the second year when all of this loss was supposed to be blazed and numbered, spotters on seeing a

tree blazed would frequently pass it up thinking it had been recorded, when it had only been tallied the previous summer.

From 1927 to the present time, a new system has been adopted. Everything found unmarked is blazed, mapped, classified as to generation and recorded. This gives a much more accurate record of the percentages of current loss found on different dates. It involves complications, however, if the section is treated between the time of the first and second cruise.

Some good data might be secured from the treated sections to determine the percentages of winter loss found in the late fall and winter, and in fact some of this has been taken. But such data has not been included in the present study, since it is out of line with the general survey methods where total annual loss is generally considered.

USE OF THE CHARTS

Estimates can either be made by the use of Chart 1 or Chart 2. Up to the first of September, only Chart 1 can be used with any degree of accuracy. After September first, either method of estimating may be used.

Method One - In this case all summer and winter trees found on any date are lumped together and Chart 1 used to determine the probable total. For example, in cruising a strip or check section during the summer or fall, a certain number of newly attacked trees are found. Assume that on September 1, 90 summer trees and 20 winter trees have been found, or a total of 110. By referring to Chart 1 we find that on September 1, the visible loss should represent about 55 per cent of the total. Therefore, the estimate of the total would be 110/55 or 200 trees.

Method Two - In this case only the winter loss is considered as incomplete and from the number cruised a total winter loss estimate made by the use of Chart 2 and then to this figure the summer loss already found is added. For example, if we use Chart 2 on September 1 with the same figures as above, we find that 23 per cent of the winter loss should be visible. Therefore, the total estimate would be 20/23 plus 90 summer trees or a total of 177 trees.

On first thought the second method would seem to be the more precise, but in practice it is hardly so, because of the fewer number of winter trees upon which the estimate is based; and the inaccuracies of distinguishing in the field between summer and winter trees. One or two wrongly classified trees will throw the estimate off rather badly where only a small number of trees are used upon which to base a percentage.

In practice the two methods give about equal results. Method One tends to overestimate slightly (plus .9 per cent) and Method Two to underestimate (-3.0 per cent average). Method One is somewhat more reliable, having a standard deviation of 16.8 per cent, while Method Two has a standard deviation of 18.0 per cent.

In use these estimation charts have given the following average errors when used for estimating after September first.

Season	Method 1 Based on total loss	Method Two Based on winter loss plus summer
1923	-2.0%	----
1924	-6.1%	-3.9%
1925	+8.0%	----
1926	+ .3%	-14.2%
1927	+13.9%	+15.0%
1928	+1.8%	-8.2%
1929	-4.0%	-5.2%
Average	+ .9%	-3.0%
Standard deviation of estimate on individual sections	16.8%	18.0%
Standard deviation of average	2.2%	2.3%

THE ERRORS INVOLVED

Now we are interested in knowing how accurate our estimate will be if we use these charts. For it is more important to know the degree of accuracy of an estimate than to have an estimate of unknown reliability. Cruising data even under the best of conditions is subject to considerable inaccuracy due to the personal equation of the men forming the party; the methods of cruising employed; the trend of the epidemic and the length of the attack period. These factors must be taken into account in using such a curve, as they are apt to greatly affect the reliability of the final results. The more important errors arise from the following factors:

1. The personal errors:

Considerable variation in results will be due to the experience, interest, carefulness, and accuracy of the individual cruisers. It has been found that where one man will actually find 99 per cent of the infestation evident on an area, another will find only 75 per cent.

In the long run it may be assumed that two spotters of equal ability will mark the same number of trees, or that each spotter will mark half of the total on any section. From the cruises of 106 sections it has been determined that the standard deviation of marking for any one spotter on any section is plus or minus 20 per cent. (In other words, on at least 2/3 of the sections, a spotter will come within 20 per cent of marking half the trees), and his average for a number of sections (n) will come within 20 per cent/$\sqrt{n}$.

Therefore, to check on the personal equation of some of the men, we find the following from the cruises of recent years:

Spotters	Number Sections	Trees Spotted by Spotter 1	Trees Spotted by Spotter 2	Dev. from Av. Trees	P.ct. Error	Allowable Error
Buckhorn and Kornouhoff	8	431	431	0.0	0.0	7.1%
Wygant and Kornouhoff	9	538	528	5.0	.9	6.7%
Buckhorn and Wygant	9	621	536	42.5	7.4	6.7%
Keen and England	9	2321	2150	85.5	5.8	6.7%
England and Sabine	18	2827	2341	243.0	9.4	4.7%
	53	6738	5986			

6738
5986
12724

In general it may be said that the spotter getting the most trees will come the nearest to the actual number on his half of the section, so that if one man is consistently running low, it is probable that he is missing trees. This is not always the case, however, as the other spotter may be covering too large a strip or may be marking trees which should properly be excluded from the count.

In the last case given above, if it is assumed that the number of trees marked by spotter No. 1 is half of the total, then spotter No. 2 missed 17.2 per cent of the trees on his half. At least in this case the per cent error is nearly twice what it should be, and so it is very evident that something was wrong. This is probably enough to illustrate the point that the quality of the cruising must be high or the estimate is apt to be very much in error.

2. Errors due to methods of cruising:

The method of cruising has a pronounced influence upon the accuracy of results. If the old loss has been previously marked, so that there is no possibility of including it in the current year, a lower estimate is apt to result than if the cruise is of a new area. On a new area the tendency is always to include doubtful trees which more properly should belong to an earlier generation.

Again the intensity of the cruise will make considerable difference. The width of strip, the number of men in the crew, and the rapidity with which the ground is covered, are all factors affecting the final result. In one case a three-man crew using ten-chain strips (five chains per spotter) picked up 50 per cent more trees than were found on the same area by a five-man crew taking a twenty-chain strip (five chains per spotter). With the larger crew the tendency was to bunch around the compassman and leave the outer strips poorly covered. In another case during fall cruising, a five-man crew using 2½-chain strips each obtained 17.8 per cent more trees than would have normally been found by a three-man crew at that time of the year.

3. Errors due to time of year:

Estimates made on the basis of the early attacks in July will necessarily be very inaccurate. Obviously the accuracy of the estimates will improve during the late summer and fall as a higher percentage of the total attacks become evident.

Comparing the accuracy, using Method One, by months, the cruising data for the past seven years gives the following results:

Estimates Made in	Standard deviation of estimate on any one section	Standard error of estimate for an average of 12 sections
July	81.4% error	23.5% error
August	33.0% "	9.5% "
September	21.4% "	6.2% "
October	13.8% "	4.0% "
Any time after Sept. 1	17.5% "	5.0% "

Theoretically after the first of November it is possible to find all of the infested trees, provided the spotting is intensive enough, since all that are going to be have been attacked. However, in practice we know that, with the usual methods of cruising, 100 per cent of the trees are rarely found in the fall. In fact with the usual three-man crew 90 per cent is nearer right. The data is not adequate to determine the errors of late fall cruising. But since the standard deviation for work in October, using the standard three-man crew, is 13.8 per cent, it probably is about 10 per cent for work in November and December. And since the percentage of trees found cannot be greater than 100 per cent, the values will fluctuate between 80 per cent and 100 per cent with the average around 90 per cent. Therefore, it is safe to assume that with a three-man crew, after the first of November, about 90 per cent of the trees will be found if the work is carefully done.

Weather conditions, especially snowy or cloudy days, may also interfere to bring the actual percentage much lower than the theoretical.

4. Errors due to Variation of the Seasons:

In some years when spring comes early and the autumns are mild, the period of beetle activity is very long. In other years with late cold springs and a short summer, it has been noticed that attacks are completed much earlier than usual. In such a case a much higher percentage of the total loss will be found on any given date than in years when the attack period extends later into the fall. This was particularly noticeable in 1927 when the use of the estimating graph gave an overestimate of approximately 14 per cent.

An analysis of the records shows the variations by seasons as follows:

Season	Dates on which a given percentage of the Total Seasonal Loss was found	
	50% found	75% found
1923	Sept. 9	Sept. 18
1924	Sept. 1	Oct. 1
1926	Sept. 1	Sept. 27
1927	Aug. 10	Sept. 8
1928	Aug. 20	Sept. 22
1929	Aug. 22	Sept. 22
Range	Aug. 10 - Sept. 9	Sept. 8 - Oct. 1
Mean	August 25	Sept. 24

A study of the weather records in regard to this factor brought out a rather striking correlation between number of clear days and the variations in seasonal estimating--or departures from the average. This is illustrated in Chart 3.

The number of clear days is a good measure of the length of the growing season and the period of activity of the beetles. In 1926 with 180 clear days, a normal percentage of trees were found on any date. In 1927 with a very short season, there was an overestimate of 14 per cent. In 1928 with 176 clear days, estimating was again normal, while in 1929 with a very long season of 204 days the use of the average chart line gave an underestimate of 4 per cent. This data indicates that attacks are spread out through the season depending upon the length of favorable weather. On the other hand, there is no apparent correlation between the number of clear days and the amount of attack. Thus a long season does not necessarily mean more infestation, nor a short season less infestation, as has often been supposed. The quantity of infestation is dependent upon other factors. The distribution of attacks alone is influenced by the length of the season.

5. Errors due to Sudden Change in Infestation Trend:

If the infestation trend changes very markedly between summer and winter brood, the total estimated loss on incomplete data may be somewhat in error, especially if the estimate is based on records taken early in the summer. However, this error has not been as large as might be supposed. In 1928 a tremendous drop in the infestation occurred between the summer and winter attacks. In spite of this very sudden change an average overestimate of 1.8 per cent was made, which is well within the range of probable error.

CONCLUSION

Fairly reliable estimates of the seasonal loss from the western pine beetle in the western yellow pine stands of the southern Oregon-northern California region during the attack period can be made with the use of the graphs presented here, provided allowance is made for the various sources of error.

Errors may arise from personal factors, methods of cruising, the time of year the cruise is made, seasonal variations, and abrupt changes in trend.

After taking into account all the possible sources of error, the cruise of 10 sections any time after the first of September should give an estimate within 5 per cent of the actual, which is close enough for all practical purposes.

Portland, Ore.
February 6, 1931.

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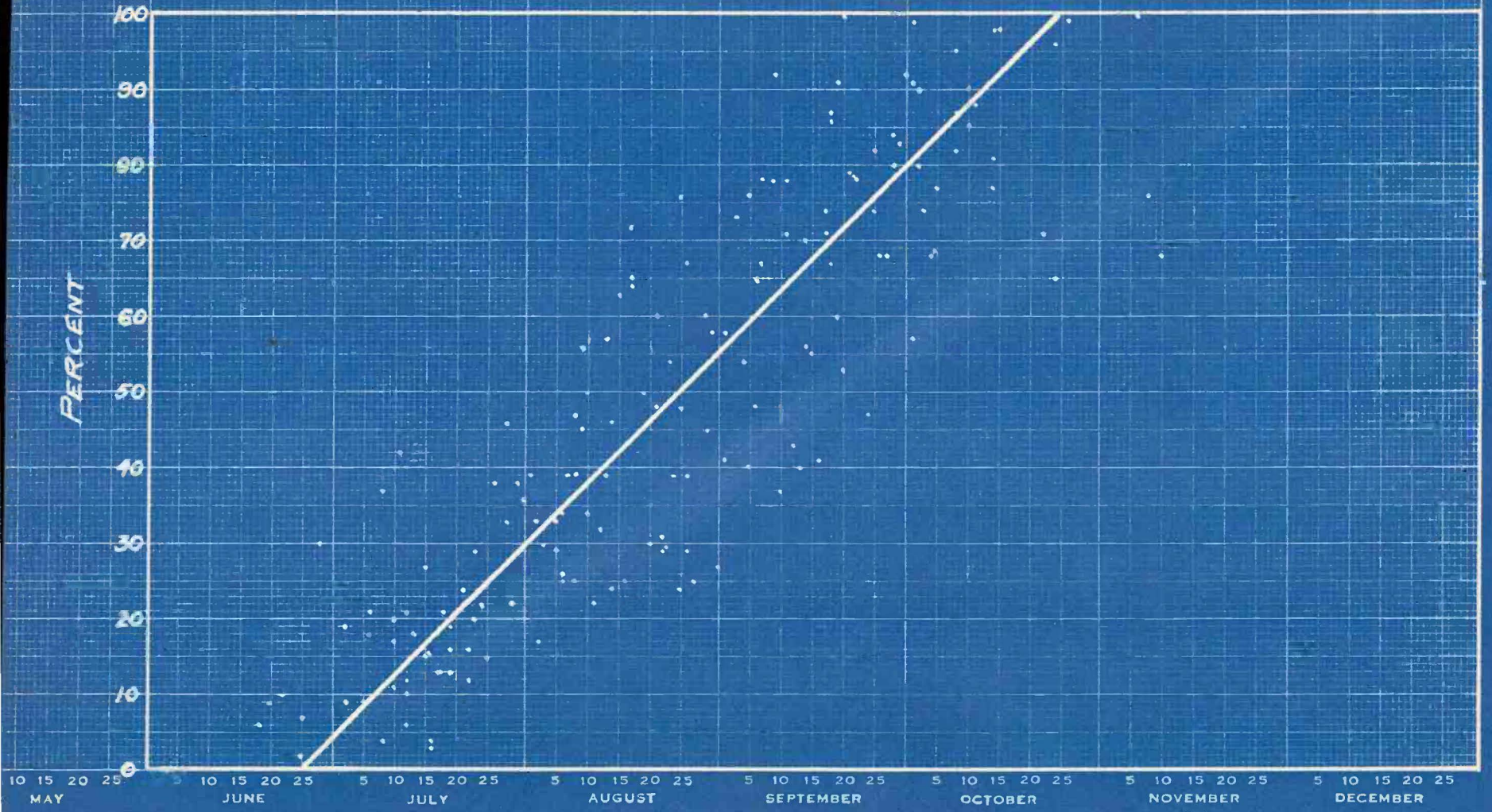
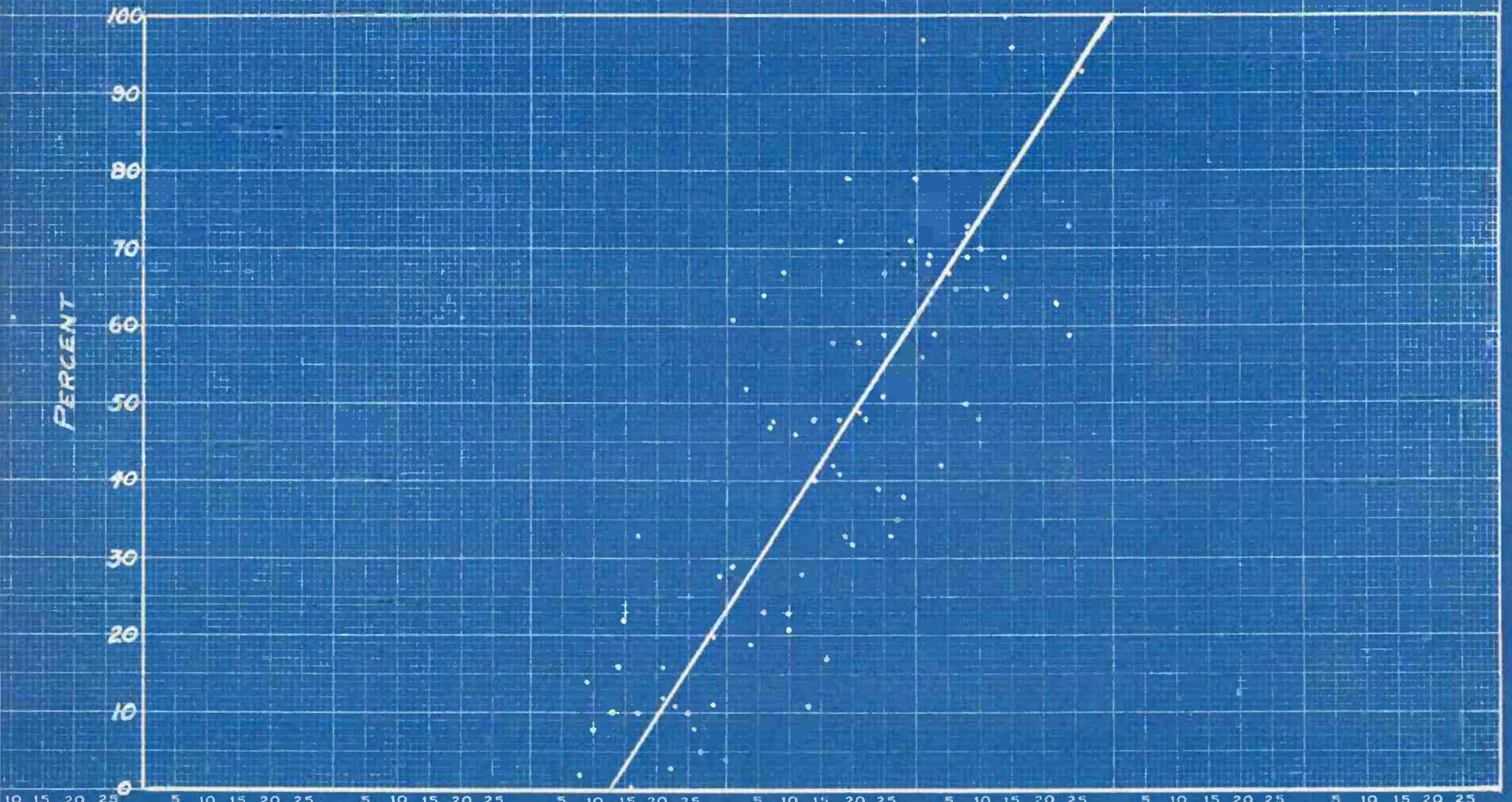
CHART No. 1
PERCENT OF TOTAL ANNUAL LOSS SPOTTED ON ANY DATE



KEUFFEL & ESSER CO., N. Y. NO. 359-141 L
One Year by Days, Calendar Year.
Divided 10 per unit vertically.

CHART No 2

PERCENT OF WINTER LOSS SPOTTED ON ANY DATE



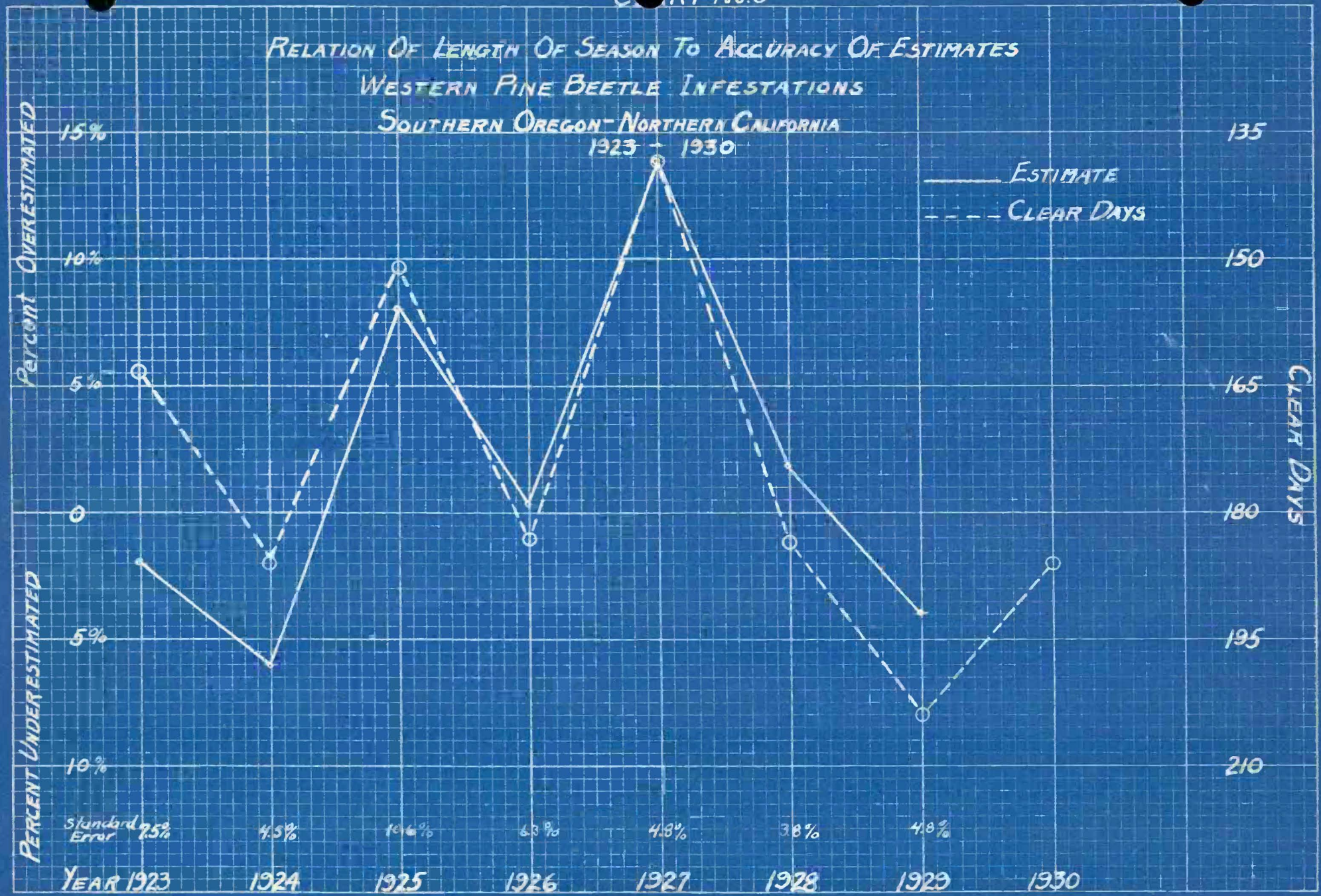
KEUFFEL & ESSER CO., N. Y. NO.369-141 L

One Year by Days. Calendar Year.

Divided 10 per unit vertically.

CHART No. 3

Relation Of Length Of Season To Accuracy Of Estimates
Western Pine Beetle Infestations
Southern Oregon - Northern California
1923 - 1930



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